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LENGTHENING OF RADIUS IN PATIENTS WITH CONGENITAL RADIAL CLUB HAND, TYPE II

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Background. Congenital radial club hand (CRCH) is characterized by longitudinal underdevelopment of the forearm and hand on the radial surface. Underdevelopment can range from hypoplasia to aplasia of the radius. More than 50 methods to correct the forearm deformities, depending on the degree of radius underdevelopment, have been proposed.

Aim. We evaluated the results of CRCH treatment using microsurgical technique and external fixation.

Methods. We analyzed 16 patients (age, 4.6 ± 0.9 years) with CRCH type II, according to the classification of Bayne and Klug, treated between 1994 and 2017. The patients were divided into two groups: Group 1 were patients undergoing microsurgical autotransplants of the epimetaphyseal second metatarsal bone with growth plate to the position of the radius defect and group 2 were patients treated by lengthening of the radius with external fixation. We analyzed the types of deformities, size of the radius defects, and range of motion in upper limb joints before the stage of the lengthening. External fixation index and number of complications also were determined. The type and number of recurrent deformities and timing of their detection were analyzed.

Results. The observation period ranged from 12 months to 10 years (average, 3.8 years). In group 1, good results were obtained in 62.5% of cases. After transplantation of the metatarsal bone growth plate, the work of the growth plate continued, characterized by increasing radius length in the later observation period. In group 2, good results were obtained in 50% of cases. Clinical and X-ray examinations showed recurrent hand deviation and radius shortening, which required repeated radius lengthening.

Conclusion. Microsurgical transplantation of the second metatarsal bone with growth plate is accepted more in reconstruction of the radial bone in patients with CRCH type II due to creation of a growth zone in the distal part of the radius. Radius lengthening via external fixation is applicable while maintaining the distal epimetaphysis and normal transverse dimensions of the radial bone.

Keywords: congenital radial club hand; lengthening; microsurgical technique; external fixation.

МЕТОДЫ ВОССТАНОВЛЕНИЯ ДЛИНЫ ЛУЧЕВОЙ КОСТИ У ПАЦИЕНТОВ С ВРОЖДЕННОЙ ЛУЧЕВОЙ КОСОРУКОСТЬЮ II ТИПА

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Введение. Врожденная лучевая косорукость — это порок развития верхней конечности, при котором наблюдается продольное недоразвитие предплечья и кисти по лучевой поверхности. При данном пороке отмечается разная степень недоразвития лучевой кости — от незначительной гипоплазии до полного ее отсутствия. Существует более 50 методов хирургического лечения деформаций предплечья в зависимости от степени недоразвития лучевой кости.

Цель исследования — оценка результатов лечения пациентов с врожденной лучевой косорукостью II типа по классификации Bayne и Klug, пролеченных методом микрохирургической аутотрансплантации кровоснабжаемого эпиметафиза второй плюсневой кости с ростковой зоной и методом удлинения лучевой кости с помощью компрессионно-дистракционного остеосинтеза.

Материалы и методы. Проведен ретроспективный анализ результатов лечения 16 пациентов с врожденной лучевой косорукостью II типа по классификации Bayne и Klug (средний возраст пациентов — 4,6 ± 0,9 года),

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которые наблюдались и получали лечение в отделении реконструктивной микрохирургии и хирургии кисти ФГБУ «НИДОИ им. Г.И. Турнера» Минздрава России в период с 1994 по 2017 г. Первая группа включала пациентов, которым производили восстановление дистального отдела лучевой кости методом микрохирургической аутотрансплантации кровоснабжаемого эпиметафиза второй плюсневой кости, включающего ростковую зону. Пациентам второй группы выполняли удлинение лучевой кости методом компрессионно-дистракционного остеосинтеза. Был произведен ретроспективный анализ результатов лечения пациентов в обеих группах.

Результаты. Длительность наблюдения составила от 12 месяцев до 10 лет (в среднем — 3,8 года). У пациентов первой группы хороший результат был получен в 62,5 % случаев. При рентгенологическом обследовании в отдаленном периоде отмечена функциональная активность ростковой зоны пересаженного трансплантата, что проявлялось в увеличении длины восстанавливаемой лучевой кости. У пациентов второй группы хорошего результата удалось добиться в 50 % случаев. При клинико-рентгенологическом обследовании отмечался рецидив девиации кисти, укорочение лучевой кости, что в последующем потребует повторного удлинения последней.

Заключение. Настоящее исследование показало, что при реконструкции лучевой кости у пациентов с врожденной лучевой косорукостью II типа микрохирургическая аутотрансплантация второй плюсневой кости, включающей ростковую зону, имеет преимущества за счет создания зоны роста в дистальном отделе лучевой кости. Однако не стоит исключать удлинения лучевой кости методом компрессионно-дистракционного остеосинтеза при сохранении дистального эпиметафиза и нормально развитых поперечных размеров лучевой кости.

Ключевые слова: врожденная лучевая косорукость; хирургическое лечение; микрохирургическая аутотрансплантация; компрессионно-дистракционный остеосинтез.

Introduction

Congenital radial clubhand is a malformation of the upper limb, which is accompanied by longitudinal underdevelopment of the forearm and the hand along the radial surface. In this defect, there may be different degrees of underdevelopment of the radial bone, from minor hypoplasia to its complete absence.

According to various authors, the incidence of this pathology ranges from 1:30,000 to 1:100,000 newborns [1]. The etiology of this disease is unknown. Most cases of congenital radial clubhand are sporadic, typically combined with various genetic syndromes [2, 3]. The pathogenesis of this disease is also unknown.

In clinical practice, classification of Bayne and Klug is most commonly used, in accordance with which there are four types of clubhand. In type I, there is a mild degree of defect in the distal epiphysis of the radial bone, which is expressed in the minimum radial deviation of the hand. Type II is characterized by restricted growth of the radial bone from proximal and distal ends. Clinically, minimum radial clubhand and moderate hand deviation are detected. Type III is characterized by the absence of two-thirds of the radial bone, most often the distal end, and severe radial deviation of the hand. In type IV, the radial bone is absent, and the hand is located perpendicular to the forearm [4].

Clubhand types III and IV are the most common. With these types, in case of the radial bone's critical underdevelopment or complete absence, reconstructive surgeries are aimed at stabilization of the hand on the ulnar bone. According to the literature, the surgery of choice in this case is hand centration [4–6]. Clubhand types I and II are much less common. Patients with radial clubhand type I do not need surgical treatment on the forearm. In patients with radial clubhand type II, there may be different variants of radial bone hypoplasia, namely 1) underdevelopment of the distal epiphysis with preservation of the growth zone and 2) absence of the distal end of the radial bone, including distal epiphysis and the epiphysial plate [7].

The surgical treatment of patients with congenital radial clubhand is aimed at restoring the length of the shortened bone, stabilize the wrist bones on the radial bone, and eliminate radial deviation of the hand.

According to the literature and experience from our clinic, surgical techniques are the most effective for radial clubhand type II, namely 1) microsurgical autografting of the vascularized epimetaphys of the second metatarsal bone and 2) elongation of the radial bone using compression-distraction osteosynthesis [6, 8, 9].

The indication for microsurgical autografting of the vascularized epimetaphys of the second metatarsal bone, including the epiphysial plate, is a defect in the distal radial bone epimetaphys with damage or absence of the distal epiphysial plate. In this case, it is not only about restoring the length of tubular bone but also about creating a growth zone at the articular surface of the wrist

joint. The presence of complex tissues' growth zones allows reconstruction of the joint at a very early age [9].

For the first time, the method of microsurgical grafting of a tissue complex with the epiphysial plate in place of a missing distal radial bone was proposed in 1940 by Dykhno [10]. He recommended the use of autograft from the metatarsal bone with epimetaphys or the head of the fibula with epiphyseal cartilage and a part of the metaphysis. Heikel [7], in an experiment on rabbits, showed the possibility of successful grafting from the epiphysial plate to the position of radial bone defect, followed by growth of grafts. According to I.V. Shvedovchenko, in patients with congenital radial clubhand, after microsurgical autografting of the vascularized epimetaphys of the second metatarsal bone, including epiphysial plate in the defect of the radial bone, long-term good results were obtained. In these patients, a "mortice" of the wrist joint has been formed, in which movements are preserved, the hand is retained in the medium position, the clubhand has been eliminated, and the growth of the limb has not been disturbed [11].

The disadvantages of microsurgical autografting of the vascularized epimetaphys of the second metatarsal bone consist of using a healthy foot as a donor area, and postoperative fixation period of the forearm takes 1.5 to 6 months [9, 12, 13].

Restoration of the length of underdeveloped radial bone is also possible using compression-distraction osteosynthesis [6, 8, 14]. According to T. Matsuno, elongation of the underdeveloped radial bone with radial clubhand type II should be started at an early age. In the author's study, the average age of patients was 16 months. Nevertheless, with the growth of the children, a relapse of the radial deviation of the hand was noted; this means that correcting the radial deviation requires multiple elongation procedures [6, 14].

Surgical treatment of patients with congenital radial clubhand is a complex and multi-step process. Indications for choosing a method of surgical treatment depending on the degree of underdevelopment of the radial bone, the timing and frequency of these interventions, and the number of complications remain unstudied.

This study aimed to evaluate the results of treatment of patients with congenital radial clubhand type II according to Bayne and Klug classification, treated by microsurgical autografting of the vascularized epimetaphys of the second metatarsal bone with the epiphysial plate and radial bone elongation method using compression-distraction osteosynthesis.

Materials and methods

A retrospective analysis of the results of treatment of 16 patients (12 boys and four girls, average age: 4.6 ± 0.9 years) with congenital radial clubhand type II according to Bayne and Klug classification, who were observed and treated in the department of reconstructive microsurgery and hand surgery in the Turner Scientific Research Institute for Children's orthopedics. This study was conducted from 1994 to 2017.

All patients were divided into two groups of eight patients each. Group 1 included pediatric patients who received microsurgical autografting of the vascularized epimetaphys of the second metatarsal bone with a functioning epiphysial plate, for restoring the length and articular site of the distal radial bone epimetaphys. Restoration of the length of the radial bone was performed to the group 2 patients by extending the radial bone with the compression-distraction osteosynthesis method. The follow-up period in both groups ranged from 12 months to 10 years, and the average follow-up period was 3.8 ± 0.9 years.

Clinical, radiological (including computer-tomographic), and statistical methods in research were used in planning the surgical intervention.

During clinical examination, both in the preoperative and postoperative periods, the amplitude of movement in the elbow and wrist joints, supination, and pronation of the forearm and the angle of radial deviation of the hand were determined.

Radiographs of the bones of the forearm with covered hand and elbow joints were performed in two standard views, and radiographs of the feet in the frontal view were also taken to assess the possibility of using metatarsal bone as a donor. X-ray examination determined the length of the bones of the forearm, shortening of the radial bone in relation to the ulnar bone, lateral dimensions of the radial bone in the distal section and preservation of the distal epiphysis of the radial bone were estimated.

The indications for microsurgical autografting of the second metatarsal bone to the position of the

radial bone defect included significant shortening of the radial bone in relation to the ulnar bone, reduction of the lateral dimension of the radial bone in the distal segment, and absence of distal radial epiphysis.

Reduction of the longitudinal dimensions while maintaining the normal values of the lateral dimensions of the radial bone, preservation of the distal epiphysis according to X-ray examination or presence of its cartilage model was an indication of an elongation of the radial bone by compression-distraction osteosynthesis.

In the postoperative period, the indicators were evaluated, namely the length of the graft obtained, time of osteosynthesis in the group 1 patients, time of distraction, period of correction, external fixation index, and length of the regenerate obtained in group 2 patients. We analyzed postoperative complications (according to the classification of J. Caton) obtained in the study groups [15, 16].

Microsurgical autografting of the vascularized epimetaphys of the second metatarsal bone involved several stages. Stages in the recipient zone included elongation of the tendon of the radial flexor of the hand, creation of diastasis between wrist bones and the radial bone and release of a neurovascular bundle that includes the cephalic vein, the radial artery, or the artery that accompanies the median nerve. Stages in the donor area comprised the harvesting of a bone graft from the second metatarsal bone, with preservation of blood vessels passing to the diaphysis (the great saphenous vein, the dorsal artery of the foot, and the dorsal or plantar metatarsal artery); capsulotomy of the metatarsophalangeal articulation and osteotomy in the proximal metaphysis of the metatarsal bone. To avoid an increase in the difference in length of forearm bones during the growth of transplanted graft, we took the graft that was obviously longer (1–1.5 cm) than it was required at the time of the surgery. To assess the condition of the blood supply to the graft, a skin flap (the so-called "buoy") was included in its composition.

The resulting graft was transferred from the foot to the recipient zone and placed in the created diastasis between the radial bone and wrist bones in the position of hand hypercorrection; fixation was made with a Kirschner wire, longitudinally inserted through the second metacarpal bone, graft and the radial bone. The anastomoses were applied between the vessels of the graft and the forearm. After removing the clips and monitoring the restoration of blood circulation in the transplant, sutures were applied in layers on the subcutaneous fatty tissue and skin.

In the donor area, reconstruction of the second metatarsal bone was performed to seven patients; in one case, it was decided to remove the second toe. The reconstruction of the second metatarsal bone consisted of performing longitudinal osteotomy of the first (71.4% of cases) or third (28.6% of cases) metatarsal bone, after which one of the fragments was displaced and placed under the proximal phalanx of the second finger. The fragments were immobilized with a Kirschner wire on the axis of a finger for a period of 4–6 weeks; the limbs were immobilized in a plaster cast.

After the wires were removed, all patients received physical therapy and conservative treatment, which was aimed at developing joint movements of the forearm and foot.

Elongation of the radial bone using compression-distraction osteosynthesis in group 2 patients was performed according to the standard technique; the wires were inserted in the proximal and distal parts of the forearm bones and fixed in two transosseous supports; the wires were inserted through metacarpal bones 2–5 in transverse direction; and the hands were fixed to the external bearings. Osteotomy was performed in the distal section of the radial bone metadiaphysis.

Distraction (by distraction rods) was started on day 7 after surgery, with 0.25 mm three times a day. During the entire period of distraction, all patients received conservative treatment (physiotherapy, exercise therapy, and massage). After maturation of the distraction regenerate, compression-distraction apparatus was dismantled, and immobilization with the plaster cast was performed for a period of 2 weeks.

The results of comprehensive examination were subjected to statistical processing with Statistica 7.0 for Windows by using parametric and non-parametric statistics. Correlation analysis with subsequent calculation of the correlation coefficient was performed, and means and standard deviations were determined.

Study results

The results are presented in Table 1.

During preoperative and postoperative periods, the amplitude of movement in the elbow joint in

Table 1

Evaluation of the results of surgical treatment of patients with congenital radial clubhand type II

Indicators	Group 1		*p*	Group 2		*p*
	before	after		before	after	
Clinical examination						
Flexion in the elbow joint, °	142.5 ± 8.5	143.8 ± 7.4	≥0.05	145 ± 5.4	146.3 ± 5.2	≥0.05
Extension in the elbow joint, °	8.2 ± 2.6	7.5 ± 3.7	≥0.05	8.8 ± 2.3	8.1 ± 2.5	≥0.05
Flexion in the wrist joint, °	48.1 ± 3.7	50 ± 5.3	≥0.05	55 ± 7.5	60 ± 13	≥0.05
Extension in the wrist joint, °	12.5 ± 3.8	13.2 ± 4.6	≥0.05	14 ± 4.2	15 ± 4.6	≥0.05
Supination of the forearm, °	58.8 ± 8.3	63.1 ± 5.3	≥0.05	42.5 ± 11.7	43.8 ± 10.9	≥0.05
Pronation of the forearm, °	36.3 ± 7.4	37.5 ± 7.5	≥0.05	68.8 ± 8.4	75 ± 6.6	≥0.05
Hand deviation angle, °	36.3 ± 5.3	14.3 ± 8.68	≤0.05	33.3 ± 8.6	14.7 ± 10.9	≤0.05
X-ray examination						
Length of the radial bone, mm	72.1 ± 20	95.4 ± 14	≤0.05	80.9 ± 46.3	91.3 ± 27.5	≤0.05
Length of the ulnar bone, mm	99.1 ± 14	106.9 ± 10.5	≥0.05	96.6 ± 26.9	102.1 ± 25.1	≥0.05
Shortening of the radial bone with respect to the ulnar bone, mm	14.3 ± 1.9	4.7 ± 2.2	≤0.05	10.1 ± 0.8	6.7 ± 3.6	≤0.05
Early postoperative period						
Elongation of the radial bone, mm	25.3 ± 2.1			16.6 ± 2.1		≤0.05
Consolidation period, days	42.8 ± 0.9			73.2 ± 5.9		≤0.05
Complications						
Inflammation of soft tissues in the exit site of transosseous elements	0 (0 %)			1 (12.5 %)		
Formation of a false joint or atrophic regenerate	0 (0 %)			3 (37.5 %)		
Dragging scars	1 (12.5 %)			0 (0 %)		
Regenerate fracture	1 (12.5 %)			0 (0 %)		

patients with congenital radial clubhand was not significantly different in both groups and was within the normal range. Two patients of group 1 and three patients of group 2 had mild extension contracture in the elbow joint, limited flexion and extension in the wrist joint, and decreased amplitude of pronation and supination, which was associated with an underdevelopment of the distal radioulnar joint.

The deviation angle of the hand was comparable in both groups. Group 1 patients had a radial bone length of 12% less than that in group 2 patients, but these differences were not statistically significant. The length of the ulnar bone was comparable in both groups. In group 1 patients, shortening of the radial bone in relation to the ulnar bone was greater by 41.5% compared to that in group 2 patients. The length of the graft formed from the second metatarsal bone was 76.9% (on average, 11 ± 0.3 mm) longer than the original shortening. In group 2 patients, the length of the regenerate obtained was 64.4% (on average, 9.9 ± 0.4 mm) longer than the initial shortening. Due to possible growth retardation of the radial bone, we deliberately created hypercorrection. The term of fixation in the postoperative period in group 1 patients was 42.8 ± 0.9 days, and in group 2, it was 73.2 ± 5.9 days (the fixation index averaged

47.8 days/cm; the osteosynthesis index averaged 52.1 day/cm). Thus, in group 1, the fixation period was 59% less than in group 2, which enabled joint movements of the upper limb to start developing earlier.

According to Caton classification, complications of degrees I–II were recorded only in the group 2 patients. In 12.5% of cases, the degree I complications were registered. The inflammatory process was stopped by antibiotic therapy and dressings with various antiseptics. No signs of deep infection were noted. In three cases (37.5%), degree II complications were observed in group 2 patients. Due to delayed osteogenesis after distraction, the radial bone defect grafting was required with a free cortical/spongious bone graft.

Degree III complications occurred in 12.5% of cases in group 1 patients. Two months after the surgery, a fracture was registered in the zone of consolidation of the radial bone with graft, which was due to an insufficient duration of fixation with a wire.

Relapse of hand deviation occurred in both groups. Two patients in group 1 manifested relapse, which was caused by retarded growth of the transplant. Subsequently, additional surgical interventions were required to eliminate the existing deformities. In four group 2 patients, recurrence of hand deviation was due to the retarded growth of the radial bone in relation to the ulnar bone, which further required additional elongation of the radial bone in three patients. In one case, because of a pronounced thinning of the radial bone, we had to perform microsurgical autografting of the vascularized epimetaphys of the second metatarsal bone, including the epiphysial plate.

Discussion

We examined the two most commonly used methods for restoring the length of the radial bone in congenital radial clubhand type II, namely microsurgical autografting of the vascularized epimetaphys of the second metatarsal bone, including the epiphysial plate, and elongation of the radial bone by distraction osteosynthesis.

The method of restoring the length of the radial bone was determined individually for each patient when the examination results had been received. With a significant shortening of the radial bone compared with the ulnar bone, a decrease in the transverse dimensions in the distal section, and absence of the distal epiphysis of the radial bone, the method of choice was microsurgical autografting of the second metatarsal, including the epiphysial plate.

According to reported studies, after microsurgical autografting of the second metatarsal bone, including the "live" epiphysial plate, good longitudinal growth of the graft is subsequently observed [8, 9, 13, 17, 18]. In our cases, similar results were recorded in 62.5% of cases. The main disadvantage of this surgical treatment is the use of a healthy foot as a donor area with its simultaneous reconstruction. However, good cosmetic results on the foot and absence of pain syndrome do not affect the quality of life of patients [8, 12, 17]. Over a long period, only one patient in group 1 had complained about the dragging scar of the dorsal surface of the foot, which required surgical intervention.

According to the literature, the most frequent complication after microsurgical autografting of the second metatarsal bone is inflammation, but we did not register any inflation in our study. In addition, reduced growth rate of the transplanted second metatarsal bone requires corrective surgeries on the radial bone to prevent recurrence of hand deviation [12, 13]. In our cases, two patients in group 1 were subjected to a single elongation of the radial bone using compression-distraction osteosynthesis.

I.V. Shvedovchenko reported that the wires used to fix the autograft were removed 4–6 weeks postoperatively [9]. In the postoperative period, S. Vilkki used combined osteosynthesis (fixation of fragments with a wire for 4–6 weeks, fixation of the forearm with Ilizarov apparatus for 8–9 weeks after removal of the wires), followed by immobilization of the upper limb with a plaster bandage for up to 4 weeks [12, 13]. In group 1 patients, we removed the wires 4–6 weeks postoperatively. Decreased fixation term, active early development of joint movements in the hand in 12.5% of cases led to a fracture at the level of consolidation of fragments and relapse of hand deviation. With an increased fixation with a wire or extra-cortical osteosynthesis, the risk of fracture in the site of consolidation of bones can be reduced, thus subsequently preventing recurrence of hand deviation.

There are a limited number of studies devoted to the elongation of the radial bone in pediatric patients

with congenital radial clubhand type II. However, all authors reported recurrence of hand deviation when compression-distraction osteosynthesis was used [6, 14, 19]. Decreased length of the radial bone can be caused by a decreased height of the regenerate after elongation and by bone resorption in the distal radial bone. We observed this type of dystrophy of the elongated segment in 50% of cases in group 2 patients. According to reported studies, the causes of this process include hypoplasia of soft tissues and vessels around the distal radial bone, insufficient compression in the distal radioulnar joint, and imbalance between pressure and tension in the Ilizarov apparatus [14, 20, 21].

In group 2 patients, the fixation index averaged 47.8 days/cm, and the osteosynthesis index was 52.1 days/cm, which is comparable with that presented in the literature [14, 22, 23].

Clinical case of surgical treatment of a patient in group 1

Patient D., 6 years old, had congenital right-sided radial clubhand, hypoplasia of the first finger. For up to 3 years, the patient received conservative treatment (plastering, physiotherapy). At the age of 3 years, compression-distraction apparatus was installed to bring the hand to the middle position. A year later there was a relapse of the hand deviation. During the clinical examination, forearm shortening by 7 cm was noted, and radial deviation of the hand to 32° was registered; it was impossible to passively bring the hand to the middle position, and there was hypoplasia of the first ray (Fig. 1 *a*). It was decided to restore the radial bone by microsurgical autografting of the vascularized epimetaphys of the second metatarsal bone, including the epiphysial plate. The postoperative period included no abnormalities. Intramedullary wires on the forearm and foot were removed 6 weeks postoperatively.

On examination 3 years (Fig. 1 *b*) and 8 years (Fig. 1 *c*) postoperatively, the hand was in the middle position, and mild shortening of the radial bone was observed radiographically.

Clinical case of surgical treatment of a patient in group 2

Patient A., 4 years old, was admitted to the department with diagnosis of congenital right-sided radial clubhand, i.e., hypoplasia of the first finger. He did not receive conservative or surgical treatment in a primary care facility. During clinical examination, right forearm shortening by 3 cm was noted, radial deviation of the hand was approximately 45°, the hand could not be passively brought to middle position, and first ray hypoplasia was observed (Fig. 2 *a*). Given the mild shortening of the radial bone compared with the ulnar bone and satisfactory development of the radial bone, it was decided to restore the radial bone by compression-distraction osteosynthesis. In the postoperative period, inflammation was registered around the exit site of transosseous elements, which were stopped by dressings with surface antiseptics and intake of oral antibiotics.

After the removal of the external fixation device, thinning of the radial bone was established

a *b* *c*

Fig. 1. Radiograph of the upper limb in patient D. (*a*) Before the surgical treatment, (*b*) 3 years and (*c*) 8 years after microsurgical autografting of the vascularized epimetaphys of the second metatarsal bone, including the epiphysial plate

a *b* *c*

Fig. 2. Radiographs of the forearm of patient A., (*a*) 4 years before the surgical treatment, (*b*) after dismantling the external fixation device, and (*c*) after 1 year

(Fig. 2 *b*). At 1-year follow-up, recurrence of hand deviation and shortening of the radial bone were registered (Fig. 2 *c*).

Conclusion

The present study revealed that in the reconstruction of the radial bone in patients with congenital radial clubhand type II, microsurgical autografting of the second metatarsal bone, including the epiphysial plate, has advantages over the other method because of a growth zone in the distal radial bone. However, elongation of the radial bone by compression-distraction osteosynthesis, together with maintenance of the distal epimetaphys and normally developed transverse dimensions of the radial bone, should not be excluded.

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Ethical review. The study was conducted in accordance with the ethical standards of the Helsinki Declaration of the World Medical Association, as amended by the Ministry of Health of Russia, approved by the ethics committee of the Turner Scientific Research Institute for Children's Orthopedics. The authors received a written voluntary consent from patients (or their legal representatives) for the patients to participate in the study and for medical data to be published.

Contribution of the authors

N.V. Avdeychik was involved in the development of the examination methodology, writing of all sections of the article, and literature collection and processing. She operated three patients.

S.I. Golyana managed the study group and participation in the development of the research methodology. He operated 10 patients.

A.V. Safonov took part in the development of the study and operated seven patients.

D.Yu. Grankin took part in the data processing and prepared the summary and the list of references.

E.A. Zakharyan took part in the data processing and correction of the article.

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